GUIDE
TO
STAR-GAZING.

.NG CROSS.

GUIDE TO STAR-GAZING:

A FAMILIAR EXPLANATION

OF THE

FIRST PRINCIPLES OF ASTRONOMY

BY REFERENCE TO THE NATURAL SPHERE;

SHOWING

HOW THE ASPECT OF THE HEAVENS MAY BE READILY

CALCULATED FOR EVERY MONTH IN THE YEAR.

by Mary J. Jenkins

"They glide upon their endless way,
For ever calm, for ever bright;
No blind hurry or delay
Mark the daughters of the night;
They follow in the track of day
In divine delight."——

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1861.

PREFACE.

THE present little work is the result of some years of practical teaching, and is an attempt to give a notion of the first principles of Astronomy by reference to the natural sphere. The advantages of this plan will perhaps be obvious, when the difficulty is considered of conveying to the learner an accurate notion of the relations of heavenly bodies to our earth, by what is termed the "use of the globes." Problems may be performed with a certain amount of readiness and skill, by pupils whose general ideas are often very confused and incorrect. They are most distinctly impressed by what they see, and the false notions, often so difficult to eradicate, with which their minds are perplexed by the mechanical operations required, often retain a

All who have had an opportunity of beholding nature in the lovely glowing aspect she wears in more southern climes, will readily understand how vivid and practical becomes the study of a science, the elements of which usually offer to the learner a mass of dry and uninteresting details. As he lingers in the cool and balmy evening air, his gaze is irresistibly drawn towards the unclouded ether, and to the dazzling and fantastic shapes, to each of which the superstitious fancies of antiquity gave an outline and a name.

On returning to more northern latitudes, although the facilities for practical observation are seriously diminished, and the contrast between the dim lights struggling through a hazy atmosphere almost suggests a doubt whether they are identical with the radiant orbs of warmer skies, they still arouse an interest independent of the charm of association—an interest rarely excited by the ordinary method of study.

Before concluding, it should perhaps be stated, that the form of expression which from

experience has been found best calculated to ensure rapid comprehension in the case of young and uninstructed persons, has invariably been adopted, and that all criticism as regards precision is therefore deprecated. The occasional reference to a celestial globe will not perhaps be considered a departure from the professed plan of this work, as an ordinary ball of small dimensions will, in the hands of a skilful teacher, answer any purpose required.

It is perhaps desirable to remind all who may adopt the following elementary system, that the contents of the following pages should be committed accurately to memory, and that no real progress can be made unless every fact be consecutively explained, illustrated and distinctly impressed on the mind of the young student.

Mary Jenkins

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Q. From what are they derived?

A. From the unconscious movement of the spectator on the earth with its annual and diurnal rotations.

Q. Have the sun and stars no real motion?

A. Yes; the whole universe has a very slow movement, which is however so imperceptible that it will not affect ordinary astronomical calculations.

Q. From which movement is the daily course of the sun derived?

A. The diurnal or daily rotation of the earth on its axis, once in the twenty-four hours, at the rate of 15° an hour.

Q. What other apparent motion belongs to the Sun?

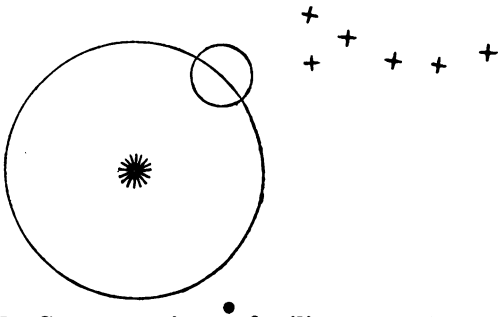
A. Its advance of about a degree a day in the signs of the Zodiac.

Q. With what real motion does this correspond?

A. With the earth's advance of about a degree a day in its annual orbit round the sun.

Q. Do the two apparent movements of the stars, resulting from the diurnal and annual rotations of the earth, correspond with the two apparent movements of the sun?

movement of the sun moves in an opposite direction to the diurnal.



Q. Can you give a familiar example that will partially illustrate the two-fold rotation of the earth?

A. The hands of a clock or watch: the minute hand corresponding to the diurnal and the hour hand to the annual rotation.

Q. What are the signs of the Zodiac?

A. They are the outer ring or belt of constellations encircling the ecliptic.

Q. What is the ecliptic?

A. The sun's apparent annual path in the heavens, derived from the earth's real movement round the sun. It is of course exactly in the same plane or level as the earth's orbit.

Q. Is it strictly correct to say that the sun is in the signs of the Zodiac?

A. No: the nearest of the fixed stars is at an immense distance from our solar system; it would therefore be more rigidly correct to say that the sun is over against any sign of the Zodiac.

Q. In what plane or level are the Zodiacal signs?

A. In about the same plane or level as the earth's orbit.

Q. Is the sun's advance of about a degree a day corresponding with the annual rotation obvious to our ordinary perceptions?

A. No, we could only note so small a change of apparent position by observing his relation to the fixed stars. As the intensity of the sun's light renders them invisible by day, it is obvious that his advance at the rate of about a degree a day is not discernible by our ordinary senses.

Q. What additional circumstance increases the difficulty of noting the sun's annual progress?

A. The annual progress of the stars can be estimated with reference to the course of time; for instance, a star that is on the meridian at

ten on the evening of any particular day, will be seen there about four minutes earlier on the following evening. As the Sun himself is the standard of time, his apparent change of position in the ecliptic or annual path, cannot be determined in the same manner.

Q. How can the sun be called the standard of time?

A. His culmination, or passing over the meridian line of any place, determines the hour of noon, from which the daily course of time is calculated.

Q. What is the meridian of any place?

A. An imaginary semicircle stretching from the north to the south points of the compass, intersecting the zenith and dividing the courses of the stars into two equal parts. Every place has of course its meridian.

Q. What is an axis of rotation?

A. An imaginary line passing through the centre of a body which revolves round it.

Q. Give a definition of a mathematical line.

A. A mathematical line has length, and not breadth.

Q. Of a point.

A. A point has neither length nor breadth.

Q. Does the axis of rotation itself rotate?

A. No: it is a mathematical line, and its extremities are mathematical points.

Q. What are its extremities called?

A. Poles.

Q. Do the heavens move in the same direction as the earth in its diurnal rotation?

A. No; the motion of the heavens is an apparent motion, and therefore the converse of that from which it is derived.

Q. What is the axis of rotation of the apparent movement of the stars?

A. It is an imaginary continuation of the axis of the earth, and any star through which it passes would be stationary likewise.

Q. Give an instance.

A. The North pole star, round which the northern celestial hemisphere appears to revolve.

Q. Is the pole star exactly at the north pole?

A. No; it is rather more than a degree distant from it, but may be used as a central point in elementary explanations.

Q. Is there any similar star over the south pole?

A. No; the stationary point of course exists, but it is not marked by any visible heavenly body.

Q. Into how many degrees is every circle supposed to be divided?

A. Into 360°.

Q. Is this true of all circles great and small?

A. Yes.

Q. How long does the earth take to make its diurnal rotation?

A. 24 hours, 360 divided by 24 gives 15° to each hour.

Q. In what space of time does the earth move round the sun?

A. In about 365¼ days. As a circle contains 360°, the earth advances at the rate of nearly a degree a day, in its annual rotation.

Q. How many movements have planets?

A. Three; two apparent, and one real.

Q. From what are the apparent derived?

A. From the annual and diurnal rotations of the earth.

Q. What is the real motion of a planet?

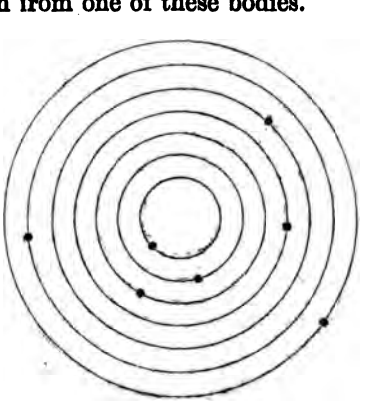
A. Its procession in an orbit round the sun.

Q. Which movement renders the position of the planets difficult of calculation?

A. The real movement.

Q. Why?

A. Some of the planets move faster, some more slowly than the earth. Some move in smaller, some in larger concentric circles round the sun. If a series of concentric circles be described, it will be obvious that bodies travelling at different rates in these differently sized circles, will present to a superficial observer, great apparent irregularity in their changes of position, especially if the point of observation be taken from one of these bodies.



Q. What is the meaning of the word concentric?

A. Having a common centre.

Q. What is a circle?

A. A superficial figure, bounded by one line called the circumference, and containing a point at equal distances from every part of the circumference: this point is called the centre.

Q. Does any other superficial figure contain a point at equal distances from the circumference?

A. No.

Q. What do you mean by a superficial figure?

A. A figure only possessing length and breadth, not depth.

Q. What solid body contains a point whose distance from every point of the surface is the same?

A. A globe or sphere.

Q. Can we fix a centre for the universe?

A. No.

Q. Why?

A. Because we cannot conceive of any limits to the universe, and cannot therefore fix on any one central point.

Q. Of what is the sun said to be the centre?

A. Of our solar system, which has clearly defined limits.

Q. Is the sun, strictly speaking, the centre of the orbits composing our solar system?

A. No; the orbits of the planets are properly ellipses, and cannot contain a common central point.

Q. In what part of the heavens are the planets always seen?

A. Always within about 8° of the ecliptic which passes against the signs of the Zodiac.

Q. Why?

A. Because the orbits of the planets are nearly in the same plane or level as the earth's orbit.

Q. What has this to do with the proximity of the planets to the ecliptic?

A. The ecliptic, or annual path of the sun, is the apparent motion derived from the real motion of the earth in its orbit. Therefore, any orbit in nearly the same plane or level as the orbit of the earth is in nearly the same plane or level as the ecliptic.

Q. Are the orbits of the planets parallel to that of the earth?

A. No; they are at angles, never exceeding 8°.

Q. What do you mean by the orbits of the planets being at angles to that of the earth?

A. I mean that the planes in which they move are inclined to each other.

Q. What is an angle?

A. An opening made by two lines which intersect or cut each other, or which would, if continued, intersect each other.

Q. How many kinds of angles are there?

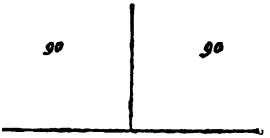
A. Three.

Q. What are they?

A. Right, acute, and obtuse.

Q. If a straight line be erected on another straight line, making two equal angles, how many degrees does each angle contain?

A. 90°; and each angle is called a right angle.



Q. Is every angle of 90° a right angle?

A. Yes.

Q. What is an acute angle?

A. An angle containing less than 90°.

Q. An obtuse angle?

A. An angle containing more than 90°.

Q. What is the difference between a star and a planet?

A. A star is a fixed body shining by its own light, which only appears to have a two-fold movement. A planet is a wandering body shining by the reflected light of the sun, which, in addition to the two-fold apparent movement derived from the earth's rotations, also progresses in an orbit of its own round the sun.

Q. How are the places of the planets ascertained?

A. By a series of astronomical calculations of a complicated nature, the results of which are to be found in an almanac.

Q. On the terrestrial globe, the equator and ecliptic are represented as being of equal dimensions, are they equal?

A. No.

Q. Which is the larger?

A. The ecliptic.

Q. How much larger is the ecliptic than the equator?

A. As much larger as the orbit of the earth is larger than the earth itself.

Q. Why is the ecliptic delineated on the terrestrial globe?

A. To show how much it is out of the plane or level of the equator, and to give the sun's declination for every day in the year.

Q. What is the relative position of the ecliptic to the equator?

A. It is at an angle of $23\frac{1}{2}^{\circ}$.

Q. Is it correct to apply the terms up, down, inclined, oblique in an astronomical sense?

A. No.

Q. Why?

A. The ideas contained in the terms up, down, &c. do not belong to universal space, but refer exclusively to the sense of gravitation possessed by human organizations.

Q. Does the term upwards always apply to the same portion of the heavens?

A. No: except at the poles, which are stationary, allowance being made for the earth's annual revolution. In the course of the earth's diurnal revolution, points of space appear in turns to be above our head or below our feet.

Q. To what alone does the word up bear reference?

A. To the position of the human body which is constantly changing.

Q. If the term up, down, inclined, &c. cannot be applied to universal space, how are the relative positions of cosmical bodies to the eye of the spectator indicated?

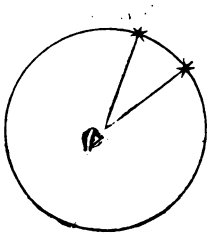
A. They are said to be at an angle to one another.

Q. What is the vertex of an angle?

A. The point at which the two lines forming an angle meet.

Q. Where is the vertex of this angle?

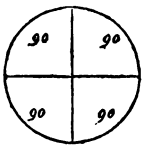
A. At the eye of the spectator, which is also the centre of an imaginary circle to which the proportions of the angle bear reference.



Q. A right angle was stated to contain 90°,

how many right angles may be contained by the circumference of a circle?

A. Four.



Q. Why, in measuring the distance of heavenly bodies, is an arc of a circle always drawn from one to another instead of a straight line?

A. Because the distance sought for is not the exact measurement given in leagues, miles, &c. as obtained on the surface of the earth, where the space measured is within the grasp of ordinary human faculties, but merely their relative position to each other in the great circle of which the eye of the spectator is the centre.

Q. As the universe cannot be conceived of as possessing any definite figure, why is it considered astronomically as a hollow globe or sphere?

A. Because the centre of this geometrical figure bears the greatest analogy to the relation of the eye of the spectator to infinite space.

Q. What is the meaning of the word analogy?

A. Likeness.

Q. Explain further.

A. Lines drawn from the centre of a globe to any point of the circumference must be equal. Lines imagined from the eye of the spectator in any direction of infinite space are also equal although they cannot be conceived of as finite.

Q. Does the measurement indicated by the expression "at an angle" refer to the actual distance of one cosmical body from another?

A. No: it merely refers to their position with regard to the eye of the spectator.

Q. What is the meaning of the word cosmical?

A. It is derived from a Greek word "Cosmos," signifying universe.

Q. When may the word cosmical be applied?

A. When a body is considered not with reference to the aspect it presents to our earth but in its relation to infinite space.

Q. If an observer could be supposed to stand at the north pole, what geometrical figure would there be described by the stars in their daily paths?

A. A series of concentric circles having the pole star for their centre.

Q. Would the whole heavens be visible to him there?

A. No: only the northern hemisphere.

Q. How long would each star take to describe its circle?

A. About 24 hours.

Q. Would the phenomena of rising and setting take place, with regard to the stars?

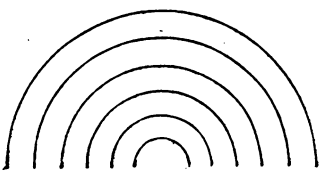
A. No: each star in the northern hemisphere would in the absence of the sun always appear above the horizon, and describe a daily circle.

Q. Would any of the stars in the southern hemisphere be ever visible?

A. No.

Q. What geometrical figures do the stars describe to observers standing at the equator?

A. Vertical semicircles.



Q. What range of the heavens is seen by a person standing at the equator?

A. The whole range from the north to the south pole; but as half the heavens must necessarily be hidden below the horizon it would take 12 hours to observe all the constellations in succession.

Q. Explain further.

A. Only half the heavens could be seen immediately after the setting of the sun, but as they revolve at the rate of 15° an hour, corresponding with the diurnal revolution of the earth, a strip of the heavens stretching from the north to the south pole would be constantly setting on the western and a similar strip constantly rising on the eastern side, until by six in the morning all the stars would in turn have appeared above the horizon.

Q. What stars would be setting at six in the morning?

A. All that were rising at six in the evening. It will thus be manifest that if an observer at the equator could watch the heavens from sun setting to sun rising, all the constellations of both the northern and southern hemispheres would in turn have appeared above his horizon.

Q. If an observer could proceed rapidly onwards, and in a straight line due north and south from the north pole to the equator, what changes would he observe in the courses of the stars?

A. The concentric circles round the pole star parallel to the horizon would gradually dip towards it; a portion of the lower one being lost beneath the horizontal line. As he proceeded onwards, the circles would dip more and more round the north point, and become more vertical until he arrived at the equator, when they would be completely vertical and semicircular.

Q. What would a nearly horizontal and circular path of the stars indicate?

A. That the observer was standing near one of the poles.

Q. Paths almost vertical and semicircular?

A. That the observer was standing near the equator.

Q. What change during his sudden progress from north to south would be observed in the position of the pole star?

A. The pole star which, while he was standing at the north pole, shone in nearly a direct line

above his head would as he advanced southward sink towards the north point of the horizon, touching it as he arrived at the equator.

Q. What is indicated by the height of the pole star?

A. The latitude of the observer.

Q. Is the pole star to be seen in the southern hemisphere?

A. No.

Q. Does the latitude of the place of observation always accord with the height of the pole star?

A. Yes: allowance being made for refraction, and the distance of the pole star from the north pole.

Q. What is refraction?

A. The bending of a ray of light passing from a rare to a denser medium, in this case from the vacuum or thin medium of space to the heavier atmosphere encircling the earth. The refracting of the rays of light causes heavenly bodies to appear higher than they are. Refraction is greater as the body approaches the horizon, but ceases at the zenith.

Q. What is parallax?

A. The difference in the apparent height of a

heavenly body, not in the zenith, as viewed from the circumference and centre of the earth.

Q. Explain further.

A. If the observer could sink downwards in space, every near object on which he fixed his eyes would appear to rise until it arrived at the zenith, where it would have reached the culminating or highest point. This phenomenon takes place on a small scale, when the point of observation is transferred from the circumference to the centre of the earth.

Q. How can it be accounted for?

A. It is evident that the depression of the point of observation, although it may raise the apparent position of the object in a vertical, cannot approximate it in a horizontal direction. The apparent approach of the body to the zenith horizontally is consequent on the perspective diminution of its horizontal distance from that point.

Q. Why should the place of observation be taken from the centre of the earth?

A. Because the position of a heavenly body must, if observed from the circumference of the earth, vary according to the point of observation, and the precision of astronomical calculation requires a fixed point.

Q. As even the centre of the earth is not a fixed point in space, what further allowance must be made in calculating parallax?

A. The difference occasioned by the earth's change of position in its annual orbit.

Q. Have the stars any sensible parallax?

A. No; with the exception of nine stars, the parallax of which has been recently discovered. It does not, however, in any case amount to a second, the 360th part of a degree.

Q. Why have the stars, generally speaking, no parallax?

A. On account of their enormous distance from our solar system.

Q. Which heavenly bodies are most affected, as regards their position, by parallax?

A. The planets; more especially the moon.

Q. Are the four points of the compass fixed points in space?

A. The north and south points are fixed, allowing for a scarcely sensible variation, caused by the revolution of the earth in its annual orbit, but the east and west points vary with the annual and diurnal rotations of the earth.

Q. How can it be proved that the north and south points are stationary?

A. The north and south poles are always directed to the same points in space. In the northern hemisphere this may be easily inferred from the nearly stationary position of the pole star.

Q. How is it that the revolution of the earth in its orbit does not more materially affect the direction of its axis in a northerly and southerly direction?

A. The dimensions of its orbit are so small as compared with its distance from the pole star, that the variation would be included within a very small area, diminishing of course as the distance increased.

Q. How can you prove that the east and west points vary with the diurnal rotation?

A. The sun, which is in reality a fixed body, is sometimes seen in the east and sometimes in the west points, according as it rises or sets.

Q. What is the zenith?

A. That point in the heavens directly over the head of the observer.

Q. What is meridian altitude?

A. The height of any heavenly body in passing the meridian line: it is then said to culminate, or reach the highest point in its apparent

daily revolution. All stars which appear to describe circles round the north and south poles will cross the line twice. At the pole, where the circles are parallel to the horizon, the points of intersection will be at equal heights. In the case of oblique circles, one point will be higher than the other.

Q. In what latitudes do stars describe oblique circles round the poles?

A. In all latitudes between the poles and the equator. The number of circles diminishes as the observer approaches the equator.

Q. What is declination?

A. The distance of any heavenly body from the equinoctial line, reckoned by degrees on a meridian.

Q. What is the equinoctial line?

A. If the plane of the equator be continued to the heavens, a circle in that plane, concentric with the equator, is the equinoctial line.

Q. Why is it so called?

A. Because, when it intersects the ecliptic twice in the year, cutting it at an angle of $23\frac{1}{2}°$, days and nights are equal all over the world. The reason of this will be hereafter explained.

Q. What is the greatest declination a star can have?

A. 90 degrees, the distance of the equinoctial from the north pole.

Q. What corresponds with declination on the terrestrial globe?

A. Declination bears an analogy to the latitude of a place on the earth's surface as reckoned from the equator.

Q. Towards which points of the compass are declination and latitude reckoned?

A. North and south.

Q. What is right ascension?

A. The distance of any heavenly body from the meridian running from north to south, and passing through the first of Aries, reckoned eastward in degrees on a parallel of declination.

Q. What is the greatest right ascension any body can have?

A. As it is reckoned round the globe, 360° of right ascension may belong to a heavenly body.

Q. What corresponds to right ascension on the terrestrial globe?

A. Longitude, east and west.

Q. What difference exists between them?

A. Right ascension is reckoned eastward

round the globe, and can number 360°; longitude is counted halfway east and west, and does not exceed 180° either way.

Q. It was stated that the height of the pole star would indicate within two degrees the latitude of the observer in the northern hemisphere; can it be ascertained from the meridian height of other stars?

A. Yes; if their declination be previously known.

Q. By what method?

A. All stars passing the meridian line between the zenith and north point of the horizon, will indicate latitude by reference to the pole star: those crossing the meridian between the zenith and south point of the horizon, will indicate it by reference to the equinoctial line.

Q. How may the latitude of the observer be determined from the meridian altitude of stars near the north pole?

A. It must be borne in mind that all stars describing circles round the pole cross the meridian twice; at the highest point of intersection they are at their greatest, at the lower at their least distance from the horizon. At

the highest point of intersection the distance of a star from the pole must be subtracted from its meridian altitude, at the lowest the distance must be added to the meridian altitude; the result will equal the meridian altitude of the pole star, which gives, within two degrees, the latitude of the observer.

Q. Give a familiar illustration.

A. If Dubhe, in the Great Bear, which is 27° from the north pole, have 37° of meridian altitude, the observer will be standing in the 10th parallel of north latitude,—that is, supposing this star had reached the highest point of its course. Twenty-seven subtracted from its meridian altitude, would leave a remainder of ten.

Q. How may this rule be applied to stars which do not appear to describe complete circles round the poles?

A. It is evident they can only cross the meridian at one and the highest point of their course. Their distance from the pole must therefore be subtracted from their meridian altitude, and the result will give the height of the pole star and latitude of the observer.

Q. How may this rule be applied to the southern hemisphere?

A. The principle is of course the same, but as no star exists at or in the immediate vicinity of the south pole, its application is not possible.

Q. What relation does the height of the equinoctial at its culminating point bear to the latitude of the observer?

A. The height of this point always indicates the distance of the observer from the north pole, from which the latitude can be reckoned.

Q. Give an example.

A. When the equinoctial, at its culminating point, has 30° of meridian altitude, the observer is 30° from the pole, and consequently has 60° of latitude. Distance from the pole subtracted from 90° will give latitude.

Q. Give another illustration.

A. ζ in Virgo is nearly intersected by the equinoctial line. At its culminating point it will indicate the distance of the observer from the north pole, and therefore the latitude of the observer.

Q. Explain further.

A. If this star at its greatest meridian height appear to have 20° of meridian altitude, the observer is 20° from the pole, and consequently is in the 70th parallel of latitude either north or south.

Q. How can it be determined in which hemisphere the observer is placed?

A. If the meridian height of this star be reckoned from the north point of the compass he is in the southern hemisphere; if from the south he is in the northern.

Q. How can the latitude of the observer be indicated by the meridian height of stars near the equinoctial?

A. By a rule similar to that given for the poles. North declination must be subtracted from meridian height, and south declination must be added to it: the result will give the meridian altitude of the equinoctial at its highest point.

Q. Give an example.

A. Regulus has 13° of north declination. When this star has 43° of meridian altitude, to an observer standing in the northern hemisphere,

the equator at its culminating point will have 30°. This indicates that the observer is standing 30° from the north pole, and, consequently, in the 60th parallel of north latitude.

Q. Give another.

A. Spica Virginis has 10° of south declination. When this star has 40° of meridian altitude to an observer standing in the northern hemisphere, the equator at its culminating point has 50°; the observer is then standing 50° from the north pole, consequently in the 40th parallel of north latitude.

Q. Is this rule available for the southern hemisphere?

A. Yes: but in reckoning meridian altitude north must be substituted for south, and south for north. North declination must be added to, and south declination subtracted from, the height of the equinoctial at its culminating point.

Q. What is amplitude?

A. The distance which a heavenly body appears to have at its rising and setting from the east and west points.

Q. What apparent amplitude have bodies if observed from the equator?

A. The courses of the heavenly bodies, if observed from the equator, appear to cut the horizon at right angles. Their amplitude will therefore always correspond exactly with their declination or distance from the equinoctial.

Q. If a vessel were to sail from the equator to the north or south pole, what changes would be observed in the rising and setting amplitude of the stars?

A. All stars having no declination, would still continue to rise and set at the east and west points of the horizon. As it advanced the amplitude of all the other stars would increase at a two-fold rate; in the first place according to the proximity of each star to the pole, and in the second according to the proximity of the observer to that point.

Q. What effect has the increase of amplitude on the daily course of a star?

A. Its path approximates more and more to the circular and horizontal course which it would present to the eye of an observer standing at either of the poles.

Q. Why do stars having no declination never increase their amplitude, that is, always

rise due east and west, whatever may be the point of observation?

A. An observer, changing his position in a line due north and south, describes the arc of a circle, the axis of whose rotation terminates at the east and west points. Its poles must be, of course, stationary, and, if the axis be continued, it will no doubt be apparent that all visible heavenly bodies whose circles of revolution pass through these poles, will never deviate at their rising and setting from the east and west points.

Q. What comparison will serve as an illustration?

A. The nearly stationary position of the pole-star during all the changes caused by the rotatory motion of the earth on its axis from west to east. If the axis of rotation be transferred to an opposite direction, the stationary point must be of course transferred to opposite points of the compass.

Apparent Path of the Sun.

Q. Will the foregoing observations apply to the daily course of the sun?

A. Yes, if allowance be made for his constant change of declination.

Q. How may his diurnal path be always ascertained?

A. By determining that of a star having the same declination.

Q. What two points must always be ascertained in determining the daily path of the sun?

A. His meridian altitude and amplitude.

Q. When has the sun no declination?

A. At the equinoxes.

Q. What is the greatest declination the sun can have?

A. Twenty-three and a half degrees.

Q. What occasions the sun's change of declination?

A. The obliquity of his apparent path, *i. e.* of the ecliptic, which is at an angle of $23\frac{1}{2}^{o}$ to the equinoctial.

Q. When does the ecliptic cross the line of the equinoctial?

A. At the equinoxes.

Q. Why are days and nights at the equinoxes equal to all the inhabitants of the earth?

A. Because at the equinoxes the diurnal course of the sun is equally divided into two semicircles, of which one is above the other below the horizon. It must be evident, from what

has been stated above, that when he is vertical to the equator his rising and setting points will remain stationary, whatever be the position of the observer, that is, he will appear to rise and set due east and west all over the globe, the points of intersection which distinguish day and night remaining the same. This subject cannot perhaps be understood without practical illustration, which may be given by means of a common ball.

Q. What is the meridian altitude of the sun at the equinoxes to an observer standing at the equator?

A. Ninety degrees.

Q. What appearance would he present to an observer standing at the poles?

A. He would have no altitude except that caused by refraction, but would be seen touching the horizon.

Q. With what does the sun's altitude at the equinoxes always correspond?

A. With the distance of the observer from the north pole.

Q. If at one of the equinoxes I observe the sun's altitude to be 40° from the south point of the horizon, where am I?

A. About forty degrees from the north pole, that is, in the 50th parallel of north latitude.

Q. If 40° from the north point of the horizon?

A. I am then in the 50th parallel of south latitude.

Q. Can the latitude of the observer be always thus determined?

A. Only at the equinoxes when the sun has no declination.

Q. How can it be ascertained at other times?

A. In the northern hemisphere north declination must be subtracted from, and south declination added to the sun's meridian altitude. In the southern hemisphere north declination must be added and south subtracted. The result will in each case give the height of the equinoctial at its highest point, which indicates distance from the pole, and from this latitude may be easily inferred.

Q. From which points of the horizon is the sun's meridian altitude always reckoned?

A. In the northern hemisphere from the south point, and in the southern from the north point of the horizon.

Q. When has the sun his greatest north declination?

A. On the 21st of June.

Q. When his greatest south declination?

A. On the 21st of December.

Q. What peculiar appearance would his annual path present to an observer standing at the poles?

A. At one of the equinoxes, in March for the northern, and September for the southern hemisphere, he would gradually appear above the horizon, skimming round it and gradually rising in spiral curves, until, after a period of three months, his greatest height would be attained, 23°½. He would then gradually descend in the same manner, and, after another period of three months, sink below the horizon at the opposite equinox to that on which he had risen.

Q. How is the year divided at the poles?

A. There are six months day and six months night, allowing for refraction which would diminish the period of darkness.

Q. What is the rule as regards the sun's increase of amplitude?

A. It is the same as that by which the am-

plitude of the stars is calculated, but his change of declination makes the reckoning more complicated.

Q. How may the sun's path always be known?

A. By calculating that of a star having the same declination.

Q. Can the amplitude of heavenly bodies be reckoned according to a system of calculation?

A. No: unless the observer be standing at the equator, where amplitude always corresponds with declination. In other cases, when an exact reckoning is required, a globe must be consulted or accurate measurements taken.

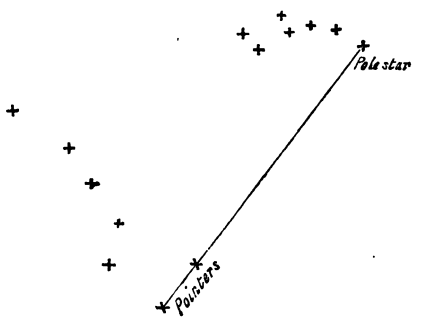
Q. In taking his first survey of the starry heavens, what method should be adopted by the inexperienced observer in the northern hemisphere?

A. The position of the pole-star should be first determined, and that of the constellations immediately revolving round it.

Q. How may the position of the pole-star be determined?

A. If the observer stand with his right hand towards the point of the heavens where the sun rises, and his left towards that where he sets,

his face will be turned towards the north pole. Before him, if the range of vision be unobstructed, will be seen Ursa Major or the Great Bear, which it is presumed he will be able to recognise. The principal stars in this constellation represent the following figure, of which the two foremost stars are called the Pointers, from their pointing immediately to the pole star.



Q. Do they always point in the same direction?

A. No. As the Great Bear revolves round the north pole once in 24 hours, it is evident he will be alternately above, below, and on each side of it. The direction of the Pointers will therefore change with his change of position.

Q. How may the accuracy of the observation be tested?

A. If the night be bright and clear and the observer have keen sight he will perceive that the pole star forms part of a constellation of an exactly similar figure, but of less size and brilliancy. Its position is also reversed, the pole-star forming the extremity of the tail.

Q. What constellations lie immediately round the north pole?

A. Ursa Major, Cepheus, Cassiopeia, Cameleopardus and Draco; Cameleopardus only contains a few stars never exceeding the 4th magnitude.

Q. How may the position of Draco be ascertained?

A. The tail of Draco lies between the Great and Little Bears, the folds of its body half encircling the latter. Three bright stars of the second magnitude would be discerned a little lower to the left. The position and configuration of the various constellations can however only be ascertained by constant reference to a chart.

Q. Why is a chart preferable to a celestial globe?

A. In looking at a celestial globe the observer stands outside the starry sphere: his position with regard to the east and west points is therefore reversed.

Q. Give an illustration.

A. Castor and Pollux, the two bright stars in Gemini, appear on the celestial globe to the right of Taurus: in the natural sphere the observer must look for them to the left of that constellation. The position of every star is reversed in a similar manner.

Q. In what respect is a chart inaccurate?

A. As a flat surface cannot represent a sphere, the relative size and bearings of the different constellations cannot be accurately given on a chart; it will however serve as a tolerable guide in observing the natural sphere.

Q. When the constellations round the north pole have been accurately marked, what portion of the heavens should then engage the attention of the observer?

A. The twelve signs of the Zodiac, forming a belt partly hidden beneath the horizon. These, with the constellations above and below them, will include that portion of the heavens visible in the latitude of London.

Q. By what very simple method may be determined with certainty what portion of the heavens is visible at any day in the year?

A. The observer must first ascertain what sign of the Zodiac culminates with the sun, and reckon from it.

Q. How is this done?

A. By means of the following table, which should be committed to memory.

♈ Aries, the Ram, 21st of March.
♉ Taurus, the Bull, 19th of April.
♊ Gemini, the Twins, 20th of May.
♋ Cancer, the Crab, 21st of June.
♌ Leo, the Lion, 22nd of July.
♍ Virgo, the Virgin, 22nd of August.
♎ Libra, the Balance, 23rd of September.
♏ Scorpio, the Scorpion, 23rd of October.
♐ Sagittarius, the Archer, 22nd of November.
♑ Capricornus, the Goat, 21st of December.
♒ Aquarius, the Waterbearer, 20th January.
♓ Pisces, the Fishes, 19th of February.

Q. What inaccuracy should be observed in the preceding table?

A. Owing to the recession of the equinoxes the sun is in arrear a whole sign.

Q. What is the recession of the equinoxes?

A. A slow progressive motion of the equinoctial points from east to west.

Q. What are the equinoctial points?

A. The points at which the ecliptic or sun's path crosses the equator, when days and nights are equal all over the earth, the reason of which has been previously explained. From these the seasons are of course calculated, their difference being occasioned by the preponderance of the sun's light and heat in either hemisphere.

Q. Why do the points of intersection recede?

A. On account of the difference between the solar and sidereal years.

Q. What do you mean by the solar year?

A. The time the sun takes in passing from one equinox to another, that is from one point of intersection to another. This period may also be reckoned from one tropic to another.

Q. What is a sidereal year?

A. The time the sun takes in passing from any fixed star until he returns to it again.

Q. Which has the greater length?

A. The sidereal year by 20 minutes 23 seconds. The points of intersection, will take

place every year a little before the apparent revolution has been completed, giving to the points of intersection, that is the equinoctial points, a slow motion from east to west.

Q. What do you mean by a slow motion?

A. I mean that these points will have a constant varying relation to the constellations that are without our solar system.

Q. Why are the equinoxes named from Aries and Libra?

A. Because in the time of the oldest astronomers the equinoctial points were fixed in those signs.

Q. It was stated that the visible portion of the heavens on any day in the year might be ascertained by a very simple method of calculation: give an example.

A. The sun is said to enter Cancer on the 21st of June. Allowance being made for the recession of the equinoxes, it will be seen that Gemini will culminate with the sun. At the opposite hour of midnight, the opposite sign, Sagittarius, will be seen full south: the 3rd sign after Sagittarius, *i. e.* ♑, will be on the eastern, and its opposite, Virgo, on the western horizon.

Q. What will be the aspect of the heavens at ten o'clock of the same evening?

A. Ten o'clock is two hours, that is a whole sign, before midnight, Sagittarius will not therefore have arrived at the meridian, where the sign immediately before it, Scorpio, will be culminating. The 3rd sign after Scorpio, that is, Aquarius, will be rising, and its opposite, Leo, setting.

Q. How may the aspect of the heavens be calculated for other hours before and after midnight?

A. After the midnight aspect has been fixed, it is easy to calculate for other hours, if it be borne in mind that the heavens, and with them the signs of the Zodiac, revolve at the rate of half a sign for one hour and a whole sign for two. If Sagittarius culminate at 12 o'clock at night the second sign before it will culminate 4 hours before midnight, and the second sign after it will be seen on the meridian at 4 o'clock in the morning.

Q. Have the foregoing remarks an universal application?

A. No: they are only strictly correct as regards observations taken at the equator.

Q. What variation in the ecliptic would be

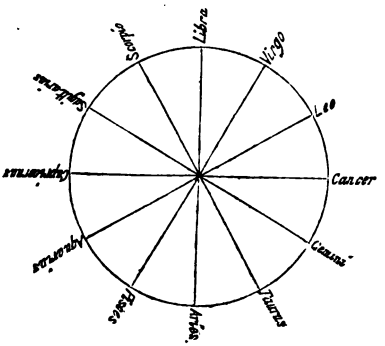
noted, in the case of an observer proceeding in a direct line from the equator to the poles?

A. At the equator, half of the ecliptic would appear above the horizon, divided into two equal portions by the meridian, the amplitude of each degree of the ecliptic corresponding with its declination. As the observer approached the poles, the divisions, intersected by the meridian, would become more and more unequal. In the latitude of London, about four zodiacal signs would be included in the northern, and two in the southern arc. This subject can scarcely be understood without reference to a globe.

Q. As it is important to recollect what signs are opposite to each other, give a table by which this may be imprinted on the memory.

A. The following mnemonic pictures will serve this purpose.

Aries, Libra, The Ram weighed in a Balance.
Taurus, Scorpio, The Bull stung by a Scorpion.
Gemini, Sagittarius, The Twins shooting Arrows.
Cancer, Capricornus, The Crab fastened to a Goat.
Leo, Aquarius, The Lion drinking Water.
Virgo, Pisces, A Maid cooking Fishes.



Q. In what part of the heavens must the observer look for the zodiacal signs?

A. From Aries to Libra, the zodiacal signs are a little to the north of the equinoctial; from Libra to Aries, they lie a little to the south of it.

Q. What relation does the equinoctial bear to the north pole?

A. The equinoctial is 90°, or the quarter of a circle from the north pole. This distance may be estimated with tolerable accuracy, if it be borne in mind that the zenith is 90° from every point of the horizon.

Q. Do the zodiacal signs rise always due east and west?

A. No: they rise a little to the north and south of the east and west points, according as they have north or south declinations, and according to the latitude of the observer, which of course would give a proportionate increase of amplitude, excepting to those points of the ecliptic which cut the equator.

Q. What are the solstitial points?

A. Those points of the ecliptic which have the greatest declination, *i. e.* 23½° north and south of the equator.

Q. In what signs of the Zodiac are they situated?

A. They are usually termed the first of Cancer and of Capricorn, but the recession of the equinoxes has altered their positions a whole sign. The sun attains his highest north declination at a point between the toe of Castor and that of Auriga: his greatest south declination at a point a little to the north of the arrow of Sagittarius.

Q. What is the amplitude of the ecliptic at the solstitial points if viewed from the equator?

A. 23½°, corresponding with the declination of the ecliptic at the solstitial points.

Q. What is the amplitude of these points in the latitude of London?

A. The northern solstitial point has 40° north amplitude, the southern solstitial point 40° south amplitude.

Q. What inference may hence be drawn?

A. That the direction of the ecliptic in the heavens will be materially changed when Gemini and Sagittarius are rising and setting, or rather when the equinoctial points are passing the meridian.

Q. Explain further.

A. When the equinoxes, *i. e.* Pisces and Virgo, culminate in the latitude of London, the northern arc of the ecliptic will be considerably lengthened, and the southern arc shortened; the former will even include four signs, and the latter two: the ecliptic then appears to cross the heavens almost diagonally, that is, from a point on the horizon between the north and east, to another between the south and west, or vice versa.

Q. What is the direction of the ecliptic when the solstitial points pass the meridian?

A. It crosses the heavens from the east to the west point of the compass, the height of each solstitial point depending on its declination being north or south of the equator.

Q. When Aries culminates with the sun, *i. e.* at noon, which zodiacal sign crosses the meridian at midnight?

A. By referring to the previous table, it will be found that Libra is the opposite sign to Aries; it will therefore be seen on the meridian at midnight.

Q. What zodiacal signs will then be rising and setting in the latitude of London?

A. The second sign after Libra, forming part of the southern arc, will be seen on the eastern, and the fourth sign before Libra, forming part of the northern arc, will be seen on the western horizon.

Q. During which month will Libra culminate with the sun and Aries at midnight?

A. According to the usual table this would appear to be the latter part of September, but allowing for the recession of the equinoxes, the succeeding month, *i. e.* the last part of October, would be found to correspond.

Q. What sign of the Zodiac culminates at midnight during the latter part of November?

A. Scorpio culminates with the sun, therefore its opposite, Taurus, will be on the meridian at midnight.

Q. Why is the latter part of the month chosen?

A. Because the sun does not enter each sign of the Zodiac until the middle of the month. The first part of every month belongs to the preceding sign.

Q. What signs of the Zodiac are culminating, rising and setting at midnight, during the latter part of the following months in the latitude of London—it should be borne in mind that the north-eastern and north-western sections of the ecliptic include four, the south-eastern and south-western two signs of the Zodiac, when the equinoctial points cross the meridian—

September,	May,
March,	January,
December,	August?

Q. What constellation of the Zodiac culminates at 10 P. M. during the latter part of November?

A. As Scorpio culminates with the sun, its opposite, Taurus, will cross the meridian at midnight. Two hours before that time, the previous sign, Aries, would be seen on the meridian.

Q. State the aspect at 2 A. M.

A. The succeeding sign to Taurus, *i. e.* Gemini, would be culminating; Virgo rising, and Pisces setting.

Q. What must be constantly borne in mind in making these calculations?

A. That opposite signs appear on the meridian at noon and midnight of the same astronomical day, and also that opposite signs rise and set about the same time. The latter is only an approximation to the exact truth even at the equator.

Q. What sign of the Zodiac culminates on the 20th of March at 10 o'clock P.M.?

November 22nd at 4 A.M.?

May 20th at 2 A.M.?

April 19th at midnight?

September 23rd at 8 P.M.?

February 19th at 6 P.M.?

May 1st at 4 A.M.?

June 22nd at 2 A.M.?

March 20th at midnight?

June 22nd at 10 P.M.?

Dec. 1st at 8 P.M.?

Feb. 19th at 4 P.M.?

April 3rd at 6 A.M.?

Q. Describe Aries and the constellations above and below it.

A. There are only two bright stars in Aries. A small constellation, Musca the Fly, Andromeda and Perseus to the north, and a part of Cetus the Whale to the south, are the only signs on nearly the same meridian as Aries.

Q. Describe Taurus.

A. The stars included in Taurus and those adjacent to it are perhaps the most brilliant in the northern hemisphere. Taurus comprises the Pleiades, Hyades, and two bright stars in the horns of the Bull. Immediately above are Perseus and Auriga: below are Eridanus and Orion.

Q. Describe Gemini.

A. Castor and Pollux are the chief stars in Gemini. Above it is a group of insignificant stars known as the Lynx; below it Canis Minor, which includes Procyon, a brilliant star of the first magnitude. Below Canis Minor is a dim constellation called Monoceros.

Q. Describe Cancer.

A. Cancer has only one bright star. On this meridian are to be seen half of the Lynx,

To the north of Cancer are the tail and head of the Great Bear: to the south the head of the Serpent. All the stars on this meridian, with one exception, are of very inferior brightness.

Q. Describe Leo.

A. All the stars on this meridian present a very brilliant aspect. Above Leo are Leo Minor and Ursa Major: below it the folds of Serpentarius.

Q. Describe Virgo.

A. Above Virgo is to be seen the tail of Ursa Major, Bootes, Coma Berenices, and Canes Venatici: below it Corvus.

Q. Describe Libra.

A. Above Libra are part of Bootes and Corona Borealis. Beneath it part of Scorpio.

Q. Describe Scorpio.

A. Scorpio is a very brilliant constellation. Above it to the left are Serpens Ophincus and Hercules: a little to the right Corona Borealis.

Q. Describe Sagittarius.

A. Sagittarius is the most southern of the Zodiacal signs. The principal constellations on the same meridian are Antinous, Aquila the Eagle, and Lyra.

Q. Describe Capricornus.

A. There are only two bright stars in Capricornus. The principal constellations to the north are Delphinus and Cygnus.

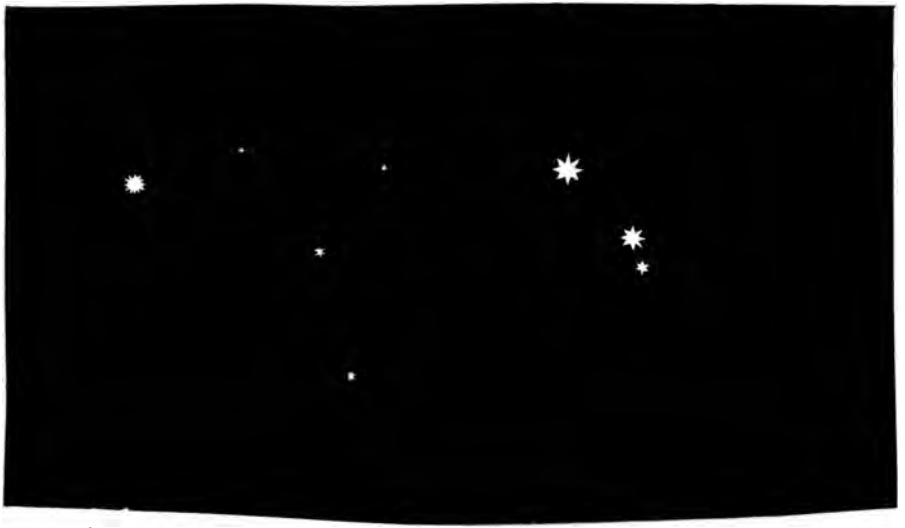
Q. Describe Aquarius.

A. Above this sign is to be seen Pegasus, and below it the Southern Fish, which includes Fomalhaut, a brilliant star of the first magnitude.

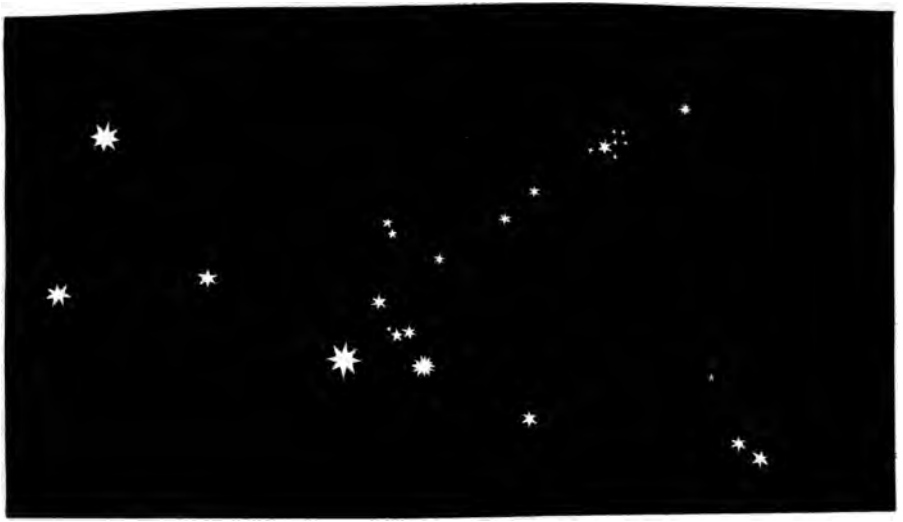
Q. Describe Pisces.

A. There are no bright stars to be seen in Pisces. Above, a little to the left, is Andromeda, and below, in the same direction, Cetus or the Whale.

THE END.

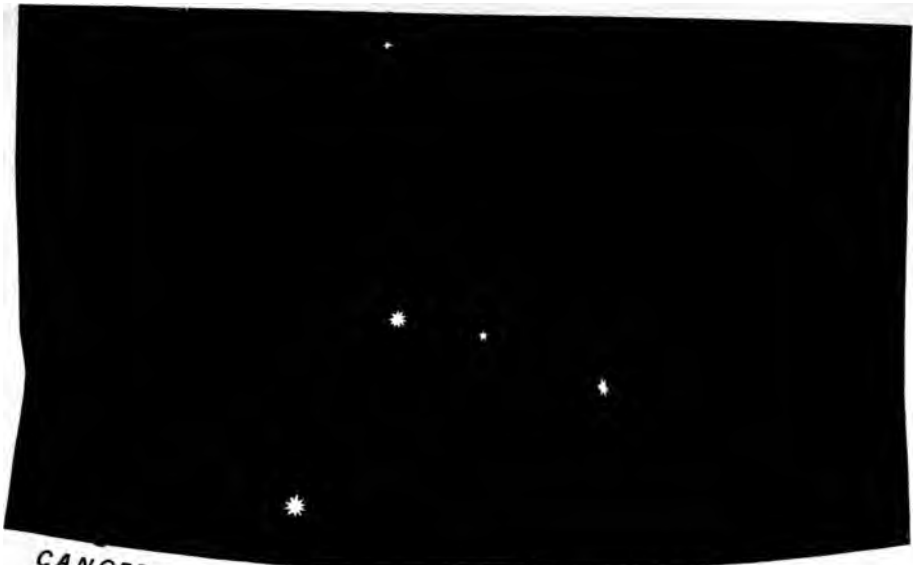


ARIES *appears on the meridian at midnight during the latter part of October.*



TAURUS *appears on the meridian at midnight during the latter part of November.*

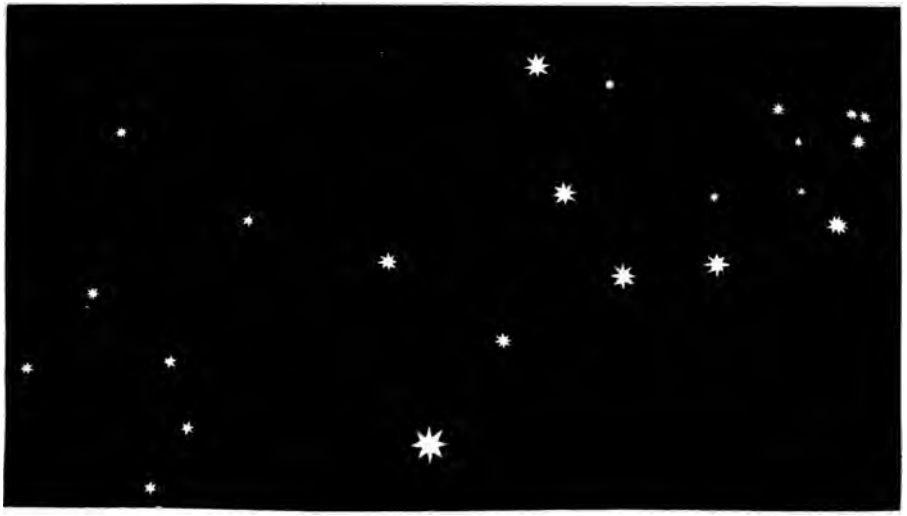
GEMINI *appears on the meridian at midnight during the latter part of December*



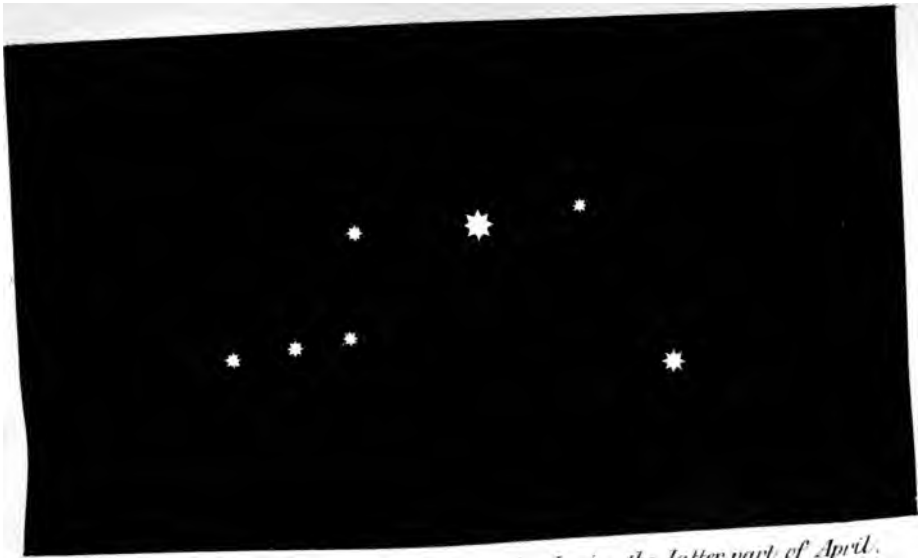
CANCER appears on the meridian at midnight during the latter part of January.

LEO *appears on the meridian at midnight during the latter part of February.*

VIRGO appears on the meridian at midnight during the latter part of March

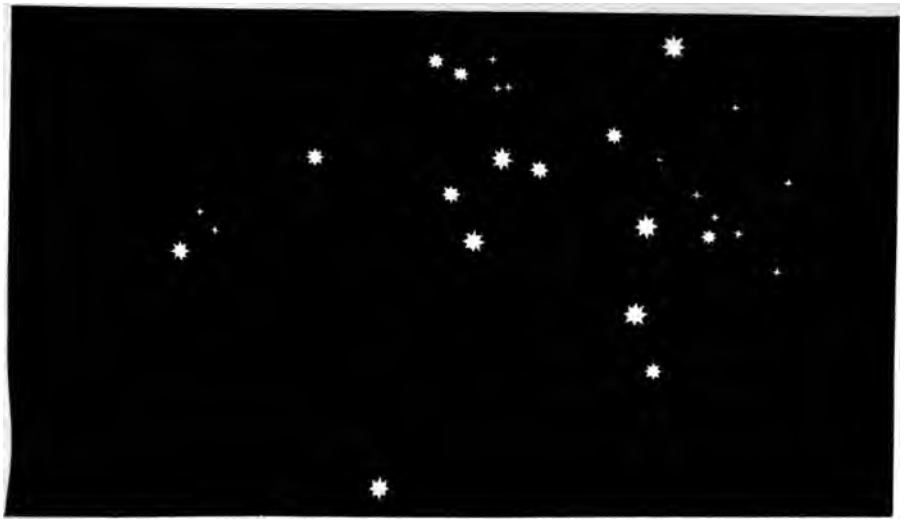


VIRGO *appears on the meridian at midnight during the latter part of March.*



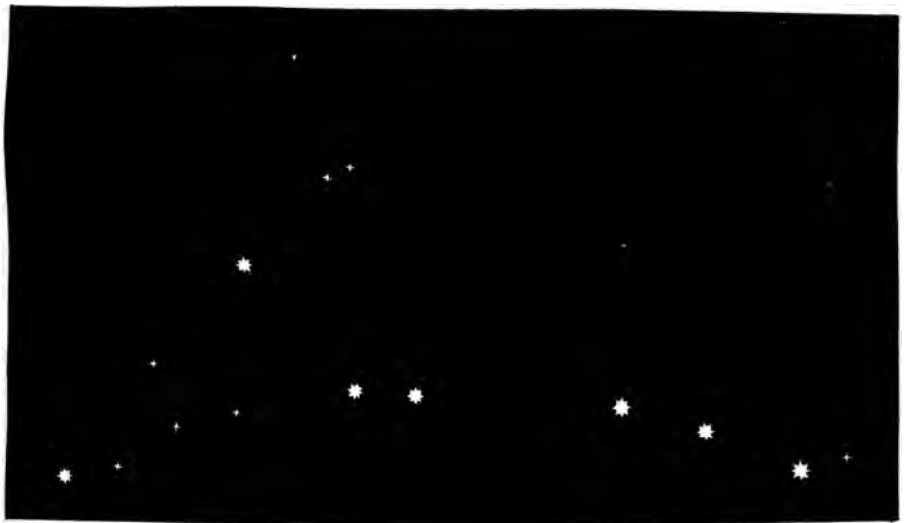
LIBRA *appears on the meridian at midnight during the latter part of April.*

SCORPIO *appears on the meridian at midnight during the latter part of May.*



SAGITTARIUS *appears on the meridian at midnight during the latter part of June.*

CAPRICORNUS *appears on the meridian at midnight during the latter part of July.*



PISCES *appears on the meridian at midnight during the latter part of September.*